1862MNRAS..23...37D

that all the faint stars in the neighbourhood were proportionably brighter than usual from the transparency of the atmosphere. The fact that Struve on three different nights overlooked the third star of Σ 2547, of which Smyth says, "It is plain enough in my refractor," and which has three or four times the light of the third star of Σ 2545 (H I. 13) is sufficient to show how easily such objects may be rendered invisible at a small altitude by a little unsuspected haze. Yet it would be highly desirable that this object should be put upon the list of "Suspected Variables." Of course, at such an altitude, great caution is required; and it will be necessary to compare it with two or three very faint objects in its immediate vicinity.

Hopefield Observatory, Haddenham,
October 1862.

Remarks on some Astronomical Eye-pieces.

By the Rev. W. R. Dawes.

As the improvement of astronomical eye-pieces must always be interesting to telescopic observers, it is hoped that a few remarks on that subject may not be unacceptable. They will have special reference to a paper by Mr. T. W. Burr, printed in the *Monthly Notices* for June 1862, in which he particularly recommends an eye-piece lately constructed by Mr. Thornthwaite, and, in consequence of its freedom from the defects of those in ordinary use, named the "Aplanatic" eyepiece.

It does not appear to be generally known that the late Carl Kellner, of Wetzlar, in Prussian Rhine, employed the same, or very nearly the same, form for his telescopes as for his microscopes—I have seen several of them. The field-lens in all was double convex; and so nearly equi-convex (in some, at least) that I could not discover that they were not exactly so. The eye-lens was a meniscus; and they all had a stop, or diaphragm, in the focus of the meniscus, and very near the field-lens. One of these, which produced a power of 80 on my telescope, had a field of 37′ 10″ in diameter; and, consequently, the angular subtense of the diaphragm = 49° 33′. Being directed to the full moon on the 8th of November, 1851, it embraced the whole of it with a considerable margin. On that night the moon's diameter was 30′ 6″; and, consequently, the breadth of the margin all round it was 3′ 32″. The focus being carefully adjusted on a well-defined object near the centre of the moon, the edge was very distinct all round without any perceptible colour.

In the year 1855, Professor Steinheil of Munich sent me three eye-pieces, the construction of which he considered an

1862MNRAS..23...37D

improvement on Kellner's; the eye-lens being rendered achromatic by being composed of a double convex of crown-glass, and a plano-concave of flint-glass, cemented together. This seems to be precisely the same combination as that of Mr. Thornthwaite's eye-lens, as described by Mr. Burr; and if so, it has already been in use for more than seven years. After many comparisons I have arrived at the conclusion, that there is little, if any, advantage in this construction over Kellner's *as made by himself.*

Mr. Burr states that "the division of double stars is rendered easier by this [aplanatic] eye-piece. . . . Persons who could not see ε *Lyræ* quadrupled with the Huyghenian of 123 had no difficulty in doing so with the aplanatic, &c." This is certainly very extraordinary. I have for many years been in the habit of showing this quadruple star, with a refractor of only 2½ inches aperture, to persons who had never seen the object before; yet no one has ever experienced any difficulty in perceiving both pairs to be double at the same time (without bringing each into the centre of the field) with the ordinary Huyghenian eye-pieces magnifying 93 and 134 times; and, as the two pairs are only about 3½ minutes of arc apart, this circumstance has never been supposed to indicate peculiar excellence in the eye-pieces. I have lately tried on this object with the same telescope a Huyghenian eye-piece by Tulley producing a power of 120, with which it was impossible for any one to overlook the duplicity of both sets seen at once. I presume that this condition (both pairs being seen double at the same time, and of course in different situations in the field of view) is one particularly dwelt upon in the comparison; because, if each is brought nearly into the centre, very little difference is produced in the image by the use of any of the various kinds of eye-piece, whether merely a single lens or composed of two. Under favourable atmospheric circumstances I have examined α *Lyræ* near the meridian with almost every variety of eye-piece,—the Huyghenian, Kellner's, and Steinheil's negatives, Ramsden's positive, or micrometer, both with ordinary and achromatic lenses; with double convex, crossed, plano-convex, and achromatic lenses;—but when the powers were nearly equal, I could perceive no difference in the definition of the disk, or in the formation of the optical rings round it; the object being, of course, placed in the centre of the field, and kept there by the driving-clock. It is, however, obviously of the utmost importance in arriving at a correct result in such a comparison, that the lenses should all be good. Any imperfection in their material or figure or workmanship may be immediately detected by a distortion of the disk of a bright star, or of the rings surrounding it; and the nature of the imperfection may probably be discovered by lengthening the focal adjustment considerably, when the defect will appear on the diffused image.

1862MNRAS..23...37D

In reference to the size and distinctness of the field in compound eye-pieces, it is of course necessary, not only that the lenses should be good, but also that their focal lengths and distances from each other should be duly proportioned and adjusted. It is quite possible that any comparative inferiority in a compound eye-piece may arise, not so much from the character of its combination, as from some fault in its construction. For instance,—any Huyghenian eye-piece producing a power of about 125 on a good telescope of two and a half inches or more in aperture, which failed to show ε *Lyræ* quadruple, may on that very account be reasonably suspected of being imperfectly constructed, and therefore unfit to be employed as a standard of comparison for others.

I have lately had an opportunity of examining a Comet eye-piece made by Mr. T. Cooke of York on Kellner's plan, which fully comes up to the standard of those made by Kellner himself; the angular subtense of the diaphragm being nearly 50°, with remarkable distinctness and freedom from colour to the edge of the field.

In the "achromatic positives," as constructed by Steinheil, the eye-lens is a double achromatic; and there is an almost complete correction of colour to the edge of the field, which would be particularly advantageous in taking wide measures with the filar micrometer. In three which I have, however, the spherical aberration is over corrected, requiring the eye-piece to be a little withdrawn to bring the web into focus when far from the middle of the field. An eye-piece of this form, with large lenses and of low power, if correctly constructed so as to unite flatness of field with achromaticity, would make an excellent comet eye-piece; and it would be even more valuable for the annular micrometer, in which the colour infesting the objects and the edges of the rings in the micrometer, is a serious impediment to the accuracy of observation.

In the preceding remarks I have spoken of the *angular subtense* of the diaphragm of an eye-piece. This is a very useful *constant*, and may be easily determined by various processes.

1. Fix the eye-piece so that its diaphragm as seen with one eye can be projected on a wall, or a perpendicular staff, as seen with the other. Let an assistant mark the points on the wall cut by the upper and lower edges of the projected diaphragm, which will denote its apparent vertical diameter. Measure the distance between them, and also the distance of the wall from the eye, which should be opposite to the middle of the projected diaphragm. Then the angular subtense of the diaphragm will be found by the following formula:—

$$\text{Tangent } \tfrac{1}{2} \text{ angular subtense} = \frac{\tfrac{1}{2}\text{ projected diameter of diaphragm}}{\text{distance of the eye}}.$$

1862MNRAS..23...37D

2. Another method of determining the same constant, and probably with greater accuracy, is by noting the time occupied by an equatoreal star near the meridian in traversing the diameter of the diaphragm of the eye-piece applied to a telescope. The magnifying power on that telescope being ascertained by a dynamometer or otherwise, the angular subtense is obtained by the formula,—

Angular subtense = time noted × 15 × magnifying power.

3. Where the eye-piece can be applied to an instrument having circles divided with sufficient minuteness, the diameter of the diaphragm in arc on that telescope can be obtained from the readings of the vertical circle, by bringing a star or any other well-defined object to the southern and northern extremities of the diameter, and taking the difference of the readings; then

Angular subtense = angular diameter × magnifying power.

It is obvious that the angular subtense, or constant, of any eye-piece having been determined, the magnifying power produced by that eye-piece on any telescope may be readily found by merely observing the diameter of the field by any of the above-mentioned methods; when

$$\text{Magnifying power} = \frac{\text{angular subtense}}{\text{angular diameter}}.$$

Thus the diaphragm of an eye-piece whose *angular subtense* is 50°, if applied to one eye, and projected on the sky viewed with the other eye, would just include at the upper edge a star whose altitude is 50°, when the lower edge coincided with the true horizon. If such an eye-piece were applied to a telescope, and an equatoreal star were found to occupy two minutes in traversing the diameter of the field, the *angular diameter* on that telescope would be 30′, and the magnifying power 100.

As the focal images formed by an object-glass lie in a spherical surface of which the radius is the focal length, it is obvious that even if the spherical aberration of an eye-piece were perfectly corrected, it could not be free from the defect of indistinctness at the edge of a field of considerable extent. I am not aware that any successful attempt has been made to *over*-correct the spherical aberration of the Huyghenian eye-piece by making the *field*-lens a compound one; though there would seem to be no impossibility in the way of its accomplishment.

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